

A STUDY OF HEIGHT TENDENCIES AT THE
500 MB LEVEL

BY
WILLIAM EDWARD HUBERT

THESIS
H84

Library
U. S. Naval Postgraduate School
Annapolis, Md.

A STUDY OF HEIGHT TENDENCIES AT THE
500 MB LEVEL

-
W. E. Hubert

A STUDY OF HEIGHT TENDENCIES AT THE
500 MB LEVEL

by
William Edward Hubert
Lieutenant junior grade, United States Navy

Submitted in partial fulfillment
of the requirements
for the degree of
MASTER OF SCIENCE
IN AEROLOGY

United States Naval Postgraduate School
Monterey, California
1950

This work is accepted as fulfilling
the thesis requirements for the degree of

MASTER OF SCIENCE
IN AEROLOGY

from the
United States Naval Postgraduate School

PREFACE

This paper presents the results of what was originally a study of 36-hour and 3-day height tendencies at the 500 mb level. This study led into further investigation on the relationship between sea level and 500 mb waves. The objectives of the paper were: first, to determine how these tendencies were correlated with other selected variables at 500 mb; secondly, to determine how far in advance and under what conditions regression equations for determining these tendencies are valid; and thirdly, to study the interdependence of 500 mb and sea level waves with special emphasis on their periodicity.

This paper was prepared at the U. S. Naval Postgraduate School, Monterey, California during 1950 in partial fulfillment of the requirement for the degree of Master of Science in Aerology.

The author wishes to acknowledge the many hours of valuable assistance and guidance given by Associate Professor Frank L. Martin of the Aerological Engineering staff.

TABLE OF CONTENTS

	Page
CERTIFICATE OF APPROVAL	i
PREFACE	ii
TABLE OF CONTENTS	iii
LIST OF ILLUSTRATIONS	iv
TABLE OF SYMBOLS AND ABBREVIATIONS	v
CHAPTER	
I. INTRODUCTION	1
II. SELECTION OF A STATION FOR STUDY AND THE SOURCES OF DATA USED	3
III. TECHNIQUE OF INVESTIGATION	
1. Formulation of the Tendency Equations	4
2.. Relationships Between Sea Level and 500 mb Waves	8
IV. RESULTS AND CONCLUSIONS	17
1. Formulation of the Tendency Equations	17
2. Relationships Between Sea Level and 500 mb Waves	20
BIBLIOGRAPHY	32

LIST OF ILLUSTRATIONS

	Page
TABLE 1. 500 mb Long Term Normal Heights and Temperatures for Columbia, Missouri.	5
TABLE 2. Comparison Between Sea Level and 500 mb Half-waves for October, 1948	10
TABLE 3. Comparison Between Sea Level and 500 mb Half-waves for November, 1948	11
TABLE 4. Comparison Between Sea Level and 500 mb Half-waves for December, 1948	12
TABLE 5. Comparison Between Sea Level and 500 mb Half-waves for January, 1949	13
TABLE 6. Comparison between Sea Level and 500 mb Half-waves for February, 1949	14
TABLE 7. Comparison Between Sea Level and 500 mb Half-waves for March, 1949	16
TABLE 8. Statistics of 36-hour Tendencies for Winter Troughs and Ridges	23
TABLE 9. Statistics of 3-day Tendencies for Winter Troughs and Ridges	24
TABLE 10. Statistics of 36-hour Tendencies for all 0300Z Data in Winter	25
TABLE 11. Statistics of Past 3-day Temperature Change and Following 3-day Height Tendency for Winter	26
TABLE 12. Statistics of 3-day Tendencies for all Winter Data	27
TABLE 13. Statistics of 3-day Tendencies for all Summer Data	28
TABLE 14. Number of Observed Semi-periods at Sea Level and 500 mb	29
FIGURE 1. Histograms for Sea Level Semi-periods of 0.5, 1.0 and 1.5 Days	30
FIGURE 2. Histograms for Sea Level Semi-periods of 2.0, 2.5 and 3.5 Days	31

TABLE OF SYMBOLS AND ABBREVIATIONS

DTG	Date time group
Fropa	Frontal passage
mb	Millibar
r	Correlation coefficient
S	Standard error of estimate
σ_i	Standard deviation about the arithmetic mean of the variate X_i (i going from 1 to 7)
S.L.	Sea level
\bar{X}_i	Arithmetic mean of variate X_i (i going from 1 to 7)
X_1	Height tendency at 500 mb for past 3 days
X_2	Deviation of 500 mb height from the long term monthly normal
X_3	Height tendency at 500 mb for following 3 days
X_4	Temperature change at 500 mb for past 3 days
X_5	Deviation of 500 mb temperature from the long term monthly normal
X_6	Height tendency at 500 mb for past 36 hours
X_7	Height tendency at 500 mb for following 36 hours
Z	Zebra or Greenwich meridian time

I. INTRODUCTION

With the ever increasing number of aircraft flights at higher and higher altitudes and the desire to more closely correlate the prognostic charts for various levels has come the need for more accurate means of forecasting the movement of troughs and ridges at upper levels. The objective of this project was to provide forecasting tools which would aid the prognostication of the 500 mb chart in the vicinity of a single station. The investigation was carried out on a purely statistical basis with no dynamic or kinematic treatment involved.

The 500 mb level was chosen because it is high enough that movements of waves are fairly regular and some of the smaller fluctuations are absent; it is not so high, however, that reports become more scarce due to Radiosonde failures. Other investigators have struggled with this same old meteorological problem of attempting to prognosticate upper and sea level wave patterns as far into the future as possible.

Aine and Johnson [1], who were concerned with making a 3-day prognostic 6-kilometer chart, made the following statement in their paper on the preparation of long range forecasts:

In general, it is reasoned that in areas where pressures are above normal and where the pressure changes for the past 72 hours have been positive over the same areas, the pressures will fall in the next 72 hours as much as they rose in the last 72 hours. Negative changes and departures from normal are considered in a similar manner.

Since the 6-kilometer and 500 mb levels are quite close to each other, their line of reasoning should also hold for height tendencies at 500 mb. The above rule would work best for troughs and ridges which are symmetrical about their center-line and have no acceleration.

The Krick [5] method of long range forecasting by the use of 'weather types' depends, basically, upon major frontal passages at the surface every 6 days with minor passages every 3 days. It would be logical to assume that trough passages aloft would have approximately the same periods. If these 3 and 6-day periods can be applied at a single station for certain lengths of time and with a reasonable accuracy, at least a start has been made toward the building of forecast tools for the 500 mb level.

The first investigations carried out in this study were more or less checks on the reliability of the two methods mentioned above when applied to a single station. These in turn led to further research to see just how far and with what accuracy tendency equations could be extended. The answer to the last problem appeared to depend to a great extent on the periods of the waves found at the 500 mb level. A desire to find out what effect 500 mb trough passages had on sea level frontal passages and vice versa led to the final study of the relationship between wave periods and ranges at these two levels.

II. SELECTION OF A STATION FOR STUDY AND THE SOURCES OF DATA USED

Columbia, Missouri (station number 445) was selected as the reporting station to be investigated. It is located at Latitude 39N, Longitude 92W and has a station elevation of 785 feet. Columbia was selected because it normally lies in the zone of upper westerlies, is considerably removed from any large body of water, and is far enough from the Rocky Mountains to be free from any 'lee-side' trough effect that might possibly extend as high as the 500 mb level.

The period covered by this study extended from October 1, 1948 through September 30, 1949; however, the greatest portion of the research was carried out for the six months from October through March. This was done because of the greater intensities of troughs and ridges during this period than during the other half-year.

All of the Radiosonde reports used in this study were taken from the Daily Upper Air Bulletins [3] and are unedited data. As a whole the reports appeared to be quite consistent, and there were very few gaps in the research period due to missing data.

The approximate times of sea level trough and frontal passages used in the latter part of this investigation were obtained from the following sources:

1. Postgraduate School Staff Analysis.
2. WBAN Facsimile Transmissions.
3. WBAN Daily Series of Synoptic Charts for January and February of 1949.

III. TECHNIQUE OF INVESTIGATION

1. Formulation of the Tendency Equations

For each of the daily soundings taken at 0300Z and 1500Z the surface pressure and temperature and the 500 mb height, temperature, and wind velocity were recorded over the year to be studied. This data was then further broken down into seven variates which were investigated using strictly statistical procedures. These variates were labeled as follows:

- X_1 Height tendency at 500 mb for the past 3 days.
- X_2 Deviation of the 500 mb height from the long term monthly normal.
- X_3 Height tendency at 500 mb for the following 3 days.
- X_4 Temperature change at 500 mb for the past 3 days.
- X_5 Deviation of the 500 mb temperature from the long term monthly normal.
- X_6 Height tendency at 500 mb for the past 36 hours.
- X_7 Height tendency at 500 mb for the following 36 hours.

Wind velocity was omitted because preliminary scatter diagrams revealed that neither West-East nor North-South wind components had any appreciable correlation with the above variates.

The long term monthly normals for Columbia were obtained from Normal Weather Maps, Northern Hemisphere Upper Level [6]. The values given in this series of charts were for pressure and temperature at the 20,000 ft. level and had to be converted to normal heights and temperatures at the 500 mb

level. These conversions were made using tables constructed by Bellamy [2]. Table 1 gives the long term normal heights and temperatures used in this study.

TABLE 1

MONTH	HEIGHT (FT)	TEMPERATURE (C)
January	18200	-22
February	18150	-23
March	18410	-21
April	18610	-19
May	18860	-15
June	19160	- 9
July	19360	- 9
August	19310	- 8
September	19160	- 9
October	18860	-14
November	18560	-18
December	18260	-23

500 mb Long Term Normal Heights and Temperatures
for Columbia, Missouri

The Aime and Johnson rule was first tested for 36-hour and 3-day height tendencies on either side of trough and ridge passages at Columbia. This investigation was carried out for the winter season only but should yield comparable results for summer as well. A timegraph of the 500 mb heights was made to facilitate the determination of times of trough and ridge passages. Any wave with a range greater than 200 feet was considered to be significant enough for study. This limitation does not appear to be inconsistent when account is taken of the diurnal variation of 135 feet which was calculated for Columbia for the winter season under consideration. Simple and multiple correlations were run for variates X_1 , X_2 , X_3 , X_6 and X_7 , and the corresponding regression equations for height tendencies were formed.

Since the correlation (for troughs and ridges) between the past 36-hour height tendency and the following 36-hour height tendency (X_6 and X_7) was quite encouraging, it was decided to examine all 0300Z winter reports using these same two variates. Only the one time was used in this study in order to eliminate any possible diurnal effect. Actually, this amounted to a test of how closely the waves at 500 mb fit a pattern that has sinusoidal waves and a 3-day period.

Correlations were next made (using all of the data divided into summer and winter seasons) between the past 3-day height tendency and the following 3-day height tendency (X_1 and X_3). This amounted to a test of a sinusoidal wave pattern with a 6-day period.

With the idea in mind that temperature changes at the 500 mb level should give some indication of the type of advection taking place at higher levels, the past 3-day temperature change was correlated with the following 3-day height tendency for all winter reports (X_3 and X_4).

Finally, height tendencies for the following and past 36 hours and 3 days were correlated with the deviations of the heights from the long term monthly normals (X_1 , X_3 , X_6 , and X_7 against X_2). The 3-day tendencies were also correlated with the deviations of temperature from the long term monthly normals (X_1 and X_3 against X_5). The results of these tests were found to be good enough to warrant multiple correlations between these variates. Simple and multiple regression equations were formed for any variates which had a correlation coefficient greater than 0.50.

2. Relationships Between Sea Level and 500 mb Waves

In order to see how the waves at sea level were related to those already studied at 500 mb, a time-graph of sea level pressures was added to the one constructed previously for 500 mb heights. This made it possible to distinguish which troughs and ridges were clearly defined at both levels and which ones appeared at one level only.

It was decided to work with half-waves because, in most cases, the time from trough to ridge was considerably different from the time from the same ridge to the next trough. A complete list was made of all half-waves; they were tabulated as to the time of passage of their mid-period. Thus, by giving the time of each mid-period and the semi-period of each half-wave (to the nearest 12 hours) it was possible to identify the time of beginning and ending of all half-waves, both at sea level and at 500 mb.

The next step was to tabulate the range of each sea level half-wave in millibars and the range of each 500 mb half-wave in feet (range being the pressure or height difference between trough and ridge or ridge and trough of each half-wave).

In all cases where there was definite evidence that a sea level half-wave could be identified with a particular half-wave aloft, the lag between the two mid-periods was computed. If the lag between the mid-periods at the two levels was greater than 30 hours the half-waves were considered to be unrelated. A further limitation was imposed in that a sea level trough or frontal passage had to be distinguishable at one end of the half wave. Surface maps were used to determine the approximate times of these passages.

Thus, a 'positive' lag means that the mid-period of the sea level half-wave passed Columbia before the mid-period of the 500 mb half-wave. The opposite order of passage corresponds to 'negative' lag.

A complete list of all half-waves studied during the winter season is given in Tables 2 through 7.

TABLE 2

Mid-Period DTG	Sea Level		Semi-Period (Days)	Lag (Hours)	500 mb		Remarks
	Semi-Period (Days)	Range (mb)			Range (mb)	500 mb Range (Ft)	
050300Z			5.0	-12	27	1230	Propa 071500Z
051500	4.0						
081500	2.0		2.0	0	12	920	
100900			1.5	-6		520	
101500	2.0				20		Propa 111500
120300	1.0				23		
122100			3.5			930	
130300	1.0				3		Propa 131800
132100	0.5				10		No effect aloft
150300	2.0			+24	19		
160300			3.0			760	Propa 161800
162100	1.5			+30	25		
180300			1.0			410	
180300	1.5			+18	13		
182100			0.5			30	Propa 191500
192100	1.5		1.5	0	4	120	
210900	1.5		1.5	0	4	440	Propa 220000
230900	2.5			+6	11		
231500			3.0			740	
272100	6.5			+6	18		
280300			6.0			460	Propa 310000
311500			1.0	-6		140	
312100	1.5				4		

Comparison Between Sea Level and 500 mb Half-Waves for October, 1948

TABLE 3

Mid-Period DTG	Sea Level		Semi-Period (Days)	Lag (Hours)	500 mb		Remarks
	Semi-Period (Days)	500 mb			Sea Level Range (mb)	500 mb Range (Ft)	
030900Z	3.5	4.5	0		24	950	Fropa 050600Z
060900	2.5		+12		32		
062100		2.5				880	
080900	1.5		+18		13		
090300		2.0				1180	Fropa 090000
100900	2.5		+18		12		
110300		2.0				920	
120300	1.0		+12		8		
121500		1.0				400	Fropa 121800
130300	1.0		+6		12		
130900		0.5				550	
140300	1.0	1.0	0		7	60	Tropa 041200
142100	0.5		+6		1		
150300		1.0				270	
152100	1.5		+12		16		
160900		1.5				580	Fropa 161800
170300	1.0		+6		11		
170900		0.5				290	
181500	2.0		+6		22		
182100		2.5				1310	Lowpa 190600
201500		1.0	+6			950	
202100	2.5				25		
222100		3.5	-12			290	
230900	2.5				12		Tropa 241200
242100Z	0.5		+6		1		
250300		1.0				330	
251500	1.0		+18		3		
260900		1.5				370	Fropa 260000Z
272100	3.5		+12		20		
280900		2.5				650	
292100	0.5		+12		3		
300900		1.5				120	Tropa 301200

Comparison Between Sea Level and 500 mb Half-Waves for November, 1948

TABLE 4

Mid-Period DTG	Sea Level 500 mb		Lag (Hours)	Sea Level Range (mb)	500 mb Range (ft)	Remarks
	Semi-Period (Days)	Semi-Period (Days)				
302100Z	1.5		+12	5		
010900		0.5			170	
020900	1.5	1.5	0	9	240	Tropa 030300
030900	0.5		+12	2		
032100		1.5			440	
041500	2.0		+18	Missing		
050900		1.5			1140	Fropa 051200
060300	1.0		+6	Missing		
060900		0.5			390	
062100	0.5			5		Tropa 070000
070900	0.5			8		Surface only
071500		2.0	-12		340	Tropa 081200
080300	1.0			2		Aloft
091500	2.0	2.0	0	19	720	
110900	1.5	1.5	0	29	300	Fropa 120600
130300	2.0	2.0	0	9	760	
142100	1.5		+18	9		
151500		3.0			460	Fropa 151200
161500	2.0		+18	25		
170900		0.5			20	
182100		2.5	-12		900	
190900	3.5			29		Fropa 210600
220300		4.0	-6		960	
220900	2.5			28		
240900	1.5		+12	3		
242100		1.5			470	Tropa 250000
251500	1.0		+30	16		
262100		2.5			480	
271500	3.0		+30	42		
282100		1.5			770	Fropa 290000
292100	1.5		+6	35		
300300		1.0			480	
310300	1.0	1.0	0	7	30	Fropa 311200
312100	0.5	0.5	0	1	130	

Comparison Between Sea Level and 500 mb Half-Waves for December, 1948

姓名	性別	年齡	職業	籍貫	學歷	備考
張三	男	25	學生	山東	高中	
李四	女	22	教師	河南	大學	
王五	男	30	工程師	浙江	大學	
趙六	女	28	醫生	湖北	大學	
陳七	男	35	商人	廣東	中學	
周八	女	20	作家	四川	大學	
吳九	男	27	律師	安徽	大學	
孫十	女	24	記者	福建	大學	
鄭十一	男	32	農民	湖南	小學	
馬十二	女	26	公務員	江西	大學	
朱十三	男	29	科學家	陝西	大學	
劉十四	女	23	藝術家	雲南	大學	
張十五	男	31	政治家	貴州	大學	
李十六	女	21	社會工作者	廣西	大學	
王十七	男	33	企業家	海南	中學	
趙十八	女	27	翻譯家	寧夏	大學	
陳十九	男	34	歷史學家	青海	大學	
周二十	女	25	心理學家	西藏	大學	
吳二十一	男	36	地理學家	新疆	大學	
孫二十二	女	28	生物學家	內蒙古	大學	
鄭二十三	男	37	物理學家	吉林	大學	
馬二十四	女	29	化學學家	遼寧	大學	
朱二十五	男	38	醫學博士	黑龍江	大學	
劉二十六	女	30	經濟學家	河北	大學	
張二十七	男	39	社會學家	山西	大學	
李二十八	女	31	政治學家	山東	大學	
王二十九	男	40	法律博士	河南	大學	
趙三十	女	32	教育學家	浙江	大學	
陳三十一	男	41	歷史學家	湖北	大學	
周三十二	女	33	地理學家	廣東	大學	
吳三十三	男	42	生物學家	四川	大學	
孫三十四	女	34	物理學家	安徽	大學	
鄭三十五	男	43	化學學家	福建	大學	
馬三十六	女	35	醫學博士	江西	大學	
朱三十七	男	44	經濟學家	陝西	大學	
劉三十八	女	36	社會學家	雲南	大學	
張三十九	男	45	政治學家	貴州	大學	
李四十	女	37	法律博士	廣西	大學	
王四十一	男	46	教育學家	海南	大學	
趙四十二	女	38	歷史學家	寧夏	大學	
陳四十三	男	47	地理學家	青海	大學	
周四十四	女	39	生物學家	西藏	大學	
吳四十五	男	48	物理學家	新疆	大學	
孫四十六	女	40	化學學家	內蒙古	大學	
鄭四十七	男	49	醫學博士	吉林	大學	
馬四十八	女	41	經濟學家	遼寧	大學	
朱四十九	男	50	社會學家	黑龍江	大學	
劉五十	女	42	政治學家	河北	大學	
張五十一	男	51	法律博士	山西	大學	
李五十二	女	43	教育學家	山東	大學	
王五十三	男	52	歷史學家	河南	大學	
趙五十四	女	44	地理學家	浙江	大學	
陳五十五	男	53	生物學家	湖北	大學	
周五十六	女	45	物理學家	廣東	大學	
吳五十七	男	54	化學學家	四川	大學	
孫五十八	女	46	醫學博士	安徽	大學	
鄭五十九	男	55	經濟學家	福建	大學	
馬六十	女	47	社會學家	江西	大學	
朱六十一	男	56	政治學家	陝西	大學	
劉六十二	女	48	法律博士	雲南	大學	
張六十三	男	57	教育學家	貴州	大學	
李六十四	女	49	歷史學家	廣西	大學	
王六十五	男	58	地理學家	海南	大學	
趙六十六	女	50	生物學家	寧夏	大學	
陳六十七	男	59	物理學家	青海	大學	
周六十八	女	51	化學學家	西藏	大學	
吳六十九	男	60	醫學博士	新疆	大學	
孫七十	女	52	經濟學家	內蒙古	大學	
鄭七十一	男	61	社會學家	吉林	大學	
馬七十二	女	53	政治學家	遼寧	大學	
朱七十三	男	62	法律博士	黑龍江	大學	
劉七十四	女	54	教育學家	河北	大學	
張七十五	男	63	歷史學家	山西	大學	
李七十六	女	55	地理學家	山東	大學	
王七十七	男	64	生物學家	河南	大學	
趙七十八	女	56	物理學家	浙江	大學	
陳七十九	男	65	化學學家	湖北	大學	
周八十	女	57	醫學博士	廣東	大學	
吳八十一	男	66	經濟學家	四川	大學	
孫八十二	女	58	社會學家	安徽	大學	
鄭八十三	男	67	政治學家	福建	大學	
馬八十四	女	59	法律博士	江西	大學	
朱八十五	男	68	教育學家	陝西	大學	
劉八十六	女	60	歷史學家	雲南	大學	
張八十七	男	69	地理學家	貴州	大學	
李八十八	女	61	生物學家	廣西	大學	
王八十九	男	70	物理學家	海南	大學	
趙九十	女	62	化學學家	寧夏	大學	
陳九十一	男	71	醫學博士	青海	大學	
周九十二	女	63	經濟學家	西藏	大學	
吳九十三	男	72	社會學家	新疆	大學	
孫九十四	女	64	政治學家	內蒙古	大學	
鄭九十五	男	73	法律博士	吉林	大學	
馬九十六	女	65	教育學家	遼寧	大學	
朱九十七	男	74	歷史學家	黑龍江	大學	
劉九十八	女	66	地理學家	河北	大學	
張九十九	男	75	生物學家	山西	大學	
李一百	女	67	物理學家	山東	大學	

TABLE 5

Mid-Period DTG	Sea Level Semi-Period (Days)	500 mb Semi-Period (Days)	Lag (Hours)	Sea Level Range (mb)	500 mb Range (ft)	Remarks
011500Z		1.0			320	
021500	3.0			20		Profa 040600Z
030300		2.0			360	
042100		1.5			710	Tropa aloft
050900	2.5		+ 30	12		
061500		2.0			990	
071500	2.0		+ 30	13		
072100		0.5			200	Profa 090000
090900		2.5	-6		590	
091500	2.0			31		
130300	5.0		+ 18	30		Profa 151800
132100		6.5			850	
161500	2.0		+ 24	26		
171500		1.0			170	
180300	1.0		+ 12	21		
181500		1.0			630	Profa 190000
190900	1.5		+ 12	31		
192100		1.5			670	
202100	1.5		+ 6	24		
210300		1.0			Missing	Profa 211200
220300	1.0		+ 6	14		
220900		1.5			Missing	
230900	1.5		+ 12	17		
232100		1.5			90	Profa 240000
242100	1.5		+ 6	21		
250300		1.0			70	
262100	2.5		+ 18	24		
271500		4.0			1130	Profa 280000
290300	2.0		+ 24	37		
300300		1.0			440	
Data missing for the last trough of the month						

Comparison Between Sea Level and 500 mb Half-Waves for January, 1949

1. The first part of the book is devoted to a general introduction to the subject of the history of the world.

2. The second part of the book is devoted to a general introduction to the subject of the history of the world.

3. The third part of the book is devoted to a general introduction to the subject of the history of the world.

4. The fourth part of the book is devoted to a general introduction to the subject of the history of the world.

5. The fifth part of the book is devoted to a general introduction to the subject of the history of the world.

6. The sixth part of the book is devoted to a general introduction to the subject of the history of the world.

7. The seventh part of the book is devoted to a general introduction to the subject of the history of the world.

8. The eighth part of the book is devoted to a general introduction to the subject of the history of the world.

9. The ninth part of the book is devoted to a general introduction to the subject of the history of the world.

10. The tenth part of the book is devoted to a general introduction to the subject of the history of the world.

11. The eleventh part of the book is devoted to a general introduction to the subject of the history of the world.

12. The twelfth part of the book is devoted to a general introduction to the subject of the history of the world.

13. The thirteenth part of the book is devoted to a general introduction to the subject of the history of the world.

14. The fourteenth part of the book is devoted to a general introduction to the subject of the history of the world.

15. The fifteenth part of the book is devoted to a general introduction to the subject of the history of the world.

16. The sixteenth part of the book is devoted to a general introduction to the subject of the history of the world.

Mid-Period DTG	Sea Level Semi-Period (Days)	500 mb Semi-Period (Days)	Lag (Hours)	Sea Level Range (mb)	500 mb Range (Ft)	Remarks
Data missing for the first half of the ridge						
030300	2.0		+18	26		
032100		1.5			500	Propa 040000
041500	1.0		+12	11		
050300		1.0			40	
052100	1.5		+12	13		
060900		1.5			250	Propa 061200
062100	0.5		+18	9		
071500		1.0			430	
072100	1.5		+18	12		
081500		1.0			170	Propa 081500
090300	1.0		+6	18		
090900		0.5			60	
092100	0.5	0.5	0	5	170	Propa 100600
100900	0.5		+24	10		
110900		2.5			870	
112100	2.5		+24	21		
122100		0.5			100	Propa 130000
130900		0.5	-6		50	
131500	1.0			17		
141500Z	1.0		+18	17		
150900		2.5			830	Propa 150000
160300	2.0		+24	20		
170300		1.0			860	
180300	2.0		+12	12		
181500		2.0			140	Propa 191200
192100	1.5		+6	16		
200300		1.0			150	
210900	1.5		+6	8		
211500		2.0			210	Propa 220000
221500	1.0		+12	3		
230300		1.0			340	
232100	1.5		+6	13		
240300		1.0			540	Propa 241500
250300	1.0	1.0	0	14	290	
260900	1.5		+12	11		
262100		2.5			460	Propa 271200

Comparison Between Sea Level and 500 mb Half-Waves for February, 1949

TABLE 6

Mid-Period	Sea Level	500 mb								
DTG	Semi-Period (Days)	Semi-Period (Days)	Lag (Hours)	Sea Level Range (mb)	500 mb Range (Ft)	Remarks				
272100	1.5		+18	14						
281500		1.0			170					

Comparison Between Sea Level and 500 mb Half-Waves for February, 1949 (Continued)

TABLE 7

Mid-Period DTG	Sea Level		Semi-Period (Days)	Lag (Hours)	Sea Level Range (mb)	500 mb Range (Ft)	Remarks
	Semi-Period (Days)	500 mb					
010900	1.5			+ 6	7		
011500		1.0				100	Tropa aloft
022100	1.5	1.5		0	3	440	
041500	2.0			+12	18		
050300		3.0				440	Fropa 051500
061500	2.0			+12	17		
070300		1.0				420	
080900	1.5			+12	18		
082100		2.5				660	Fropa 090000
Three days data missing and two days garbled							
161500	2.0			+ 24	15		
171500		1.0				280	Fropa 171200
180900	1.5			+ 24	16		
190900		2.5				640	
201500	3.0			+18	34		
210900		1.5				690	Lowpa 220000
222100	1.5			+ 6	16		
230300		2.0				520	
240900	1.5			+ 6	12		
241500		1.0				120	Fropa 250000
250900	0.5			+12	14		
252100		1.5				200	
260900	1.5			+18	19		
270300		1.0				540	Fropa 270000
280900	2.5			+ 6	17		
281500		2.0				700	
300900	1.5			+ 6	15		
301500		2.0				870	Fropa 310000

Comparison Between Sea Level and 500 mb Half-Waves for March, 1949

IV. RESULTS AND CONCLUSIONS

1. Formulation of the Tendency Equations

In the formulation of the tendency equations, all computations dealing with heights were carried out in hundreds of feet; this same unit was used for all height variates in the resulting regression equations. In like manner, all work involving temperatures was done in degrees Centigrade.

The results of the test of the Aime and Johnson rule were highly satisfactory. The correlation obtained between the past and following 36-hour height tendencies (X_6 and X_7) for trough and ridge lines in winter indicates that this rule may be used as a reliable forecasting tool. However, caution must be used in applying this rule to systems that are changing rapidly in intensity.

The addition of the variate X_2 (deviation of height from the long term monthly normal) raised the correlation coefficient even further. The multiple regression equation for the determination of X_7 from known values of X_2 and X_6 at trough and ridge lines should be a valuable aid for 36-hour prognostication of the 500 mb height at Columbia. It is probably safe to assume that the same equation will hold reasonably well for nearby stations. Similar statistical studies at other stations should yield tendency equations that would, when used together, improve large areas of the prognostic chart under these particular conditions. Table 8 gives the results of the test of the Aime and Johnson rule for 36-hour tendencies.

IN THE YEAR 1649.

THE HISTORY OF THE REIGN OF KING CHARLES THE FIRST, IN THE YEAR 1649. BY JOHN BURNET, BISHOP OF SALTHERS.

THE HISTORY OF THE REIGN OF KING CHARLES THE FIRST, IN THE YEAR 1649.

THE HISTORY OF THE REIGN OF KING CHARLES THE FIRST, IN THE YEAR 1649.

THE HISTORY OF THE REIGN OF KING CHARLES THE FIRST, IN THE YEAR 1649.

THE HISTORY OF THE REIGN OF KING CHARLES THE FIRST, IN THE YEAR 1649.

THE HISTORY OF THE REIGN OF KING CHARLES THE FIRST, IN THE YEAR 1649.

THE HISTORY OF THE REIGN OF KING CHARLES THE FIRST, IN THE YEAR 1649.

THE HISTORY OF THE REIGN OF KING CHARLES THE FIRST, IN THE YEAR 1649.

THE HISTORY OF THE REIGN OF KING CHARLES THE FIRST, IN THE YEAR 1649.

THE HISTORY OF THE REIGN OF KING CHARLES THE FIRST, IN THE YEAR 1649.

THE HISTORY OF THE REIGN OF KING CHARLES THE FIRST, IN THE YEAR 1649.

THE HISTORY OF THE REIGN OF KING CHARLES THE FIRST, IN THE YEAR 1649.

THE HISTORY OF THE REIGN OF KING CHARLES THE FIRST, IN THE YEAR 1649.

THE HISTORY OF THE REIGN OF KING CHARLES THE FIRST, IN THE YEAR 1649.

THE HISTORY OF THE REIGN OF KING CHARLES THE FIRST, IN THE YEAR 1649.

THE HISTORY OF THE REIGN OF KING CHARLES THE FIRST, IN THE YEAR 1649.

THE HISTORY OF THE REIGN OF KING CHARLES THE FIRST, IN THE YEAR 1649.

THE HISTORY OF THE REIGN OF KING CHARLES THE FIRST, IN THE YEAR 1649.

As was to be expected, the test of the above rule applied to 3-day instead of 36-hour tendencies yielded slightly poorer results. The addition of variate X_2 (deviation of height from the long term monthly normal) gave a multiple correlation which was slightly better. It is felt, however, that the resulting regression equation provides a definite forecast tool. Table 9 gives the results of the test of the Aime and Johnson rule for 3-day tendencies.

The correlation between X_6 and X_7 for all winter-time 0300Z reports, regardless of position relative to troughs and ridges, was not strongly significant. This would seem to indicate that, while there is a definite trend for 500 mb waves to have a sinusoidal wave pattern with a period of 3 days, any attempt to use this pattern for prognostication would not be warranted. This does not imply that the basic assumption of the 'weather type' forecast method is invalid. This method does not rigidly fix the period of surface frontal passages at 3 days nor does it require that all waves be sinusoidal. The results of this test are given in Table 10.

The correlation between past and following 3-day height tendencies (X_1 and X_3) for all winter data was, surprisingly enough, as good as the one obtained for the 36-hour tendencies during the same season. Once again, this indicates that a trend for 6-day waves is present at 500 mb; however, the use of this period is also not warranted for accurate prognostication.

The addition of variate X_2 (deviation of height from the long term monthly normal) gave a multiple correlation which was considerably more significant. A multiple correlation of the following 3-day height

tendency against the temperature deviation from the long term monthly normal and the height deviation from the long term monthly normal (X_3 against X_2 and X_5) was found to yield a correlation coefficient identical to the one obtained for X_3 against X_1 and X_2 . The results of these tests are given in Table 12.

The same variates were tested for observations taken during the six summer months and found to have approximately the same correlations as for winter. Table 13 gives the results obtained for the summer season.

The correlation between the past 3-day temperature change and the following 3-day height tendency (X_3 and X_4) for all winter reports was quite low. The apparent poor relationship between 500 mb temperature changes and the type of advection at higher levels discouraged further investigation along this line. The results of this correlation are presented in Table 11.

Haurwitz [4], who was working with symmetry points for long range forecasting, came to the following conclusion:

The phenomenon of symmetry occurs often enough to be utilized in forecasting if a symmetry could be recognized upon its arrival

However, he goes on to point out that since symmetry shows little tendency to persist, it cannot be utilized for forecasting by the time it is noticed in a pressure graph.

The good correlations obtained for 36-hour and 3-day tendencies at times of trough and ridge passages are, in actuality, measures of how close these troughs and ridges are to being symmetrical. The results of the investigation of height tendencies carried out in this study bear out both of Haurwitz' two conflicting statements.

It is possible to use symmetry considerations at Columbia, Missouri for forecast periods of 36 hours, although this may not be true for stations with a different geographical location. These symmetry characteristics weaken appreciably, however, for forecast periods of 3 days.

In conclusion, the regression equations derived for 36-hour and 3-day forecast intervals in the vicinity of troughs and ridges are both useable forecast tools near Columbia. These equations are listed in Tables 8 and 9.

2. Relationships Between Sea Level and 500 mb Waves.

In order to facilitate the visualization of some of the relationships between sea level and 500 mb waves, histograms of the data compiled in Tables 2 through 7 were constructed for certain selected sea level semi-periods. The six sea level semi-periods chosen for study (0.5 through 2.5 days and 3.5 days) represent 85 out of the 90 half-waves investigated in this paper.

The histograms drawn for each of the selected semi-periods are:

- (1) Frequencies of the semi-period of the corresponding 500 mb half-waves divided into classes with intervals of one-half day.
- (2) Frequencies of lag divided into classes with intervals of 6 hours.
- (3) Frequencies of sea level range divided into three classes:
 - a. 0 to 15 mb (weak waves).
 - b. 15 to 30 mb (moderate waves).
 - c. Over 30 mb (strong waves).
- (4) Frequencies of 500 mb range divided into three classes:
 - a. 0 to 200 feet (weak waves).
 - b. 200 to 600 feet (moderate waves).
 - c. Over 600 feet (strong waves).

1. The first part of the paper is devoted to a general discussion of the problem.

2. In the second part we shall consider the case of a homogeneous medium.

3. The third part is devoted to the case of an inhomogeneous medium.

4. In the fourth part we shall consider the case of a medium with a boundary.

5. The fifth part is devoted to the case of a medium with a source.

6. In the sixth part we shall consider the case of a medium with a sink.

7. The seventh part is devoted to the case of a medium with a well.

8. In the eighth part we shall consider the case of a medium with a fracture.

9. The ninth part is devoted to the case of a medium with a fault.

10. In the tenth part we shall consider the case of a medium with a joint.

11. The eleventh part is devoted to the case of a medium with a vein.

12. In the twelfth part we shall consider the case of a medium with a dyke.

13. The thirteenth part is devoted to the case of a medium with a sill.

14. In the fourteenth part we shall consider the case of a medium with a batholith.

15. The fifteenth part is devoted to the case of a medium with a pluton.

16. In the sixteenth part we shall consider the case of a medium with a stockwork.

17. The seventeenth part is devoted to the case of a medium with a breccia.

18. In the eighteenth part we shall consider the case of a medium with a conglomerate.

19. The nineteenth part is devoted to the case of a medium with a sandstone.

20. In the twentieth part we shall consider the case of a medium with a shale.

21. The twenty-first part is devoted to the case of a medium with a limestone.

22. In the twenty-second part we shall consider the case of a medium with a dolomite.

23. The twenty-third part is devoted to the case of a medium with a marble.

24. In the twenty-fourth part we shall consider the case of a medium with a gneiss.

25. The twenty-fifth part is devoted to the case of a medium with a schist.

26. In the twenty-sixth part we shall consider the case of a medium with a mica-schist.

27. The twenty-seventh part is devoted to the case of a medium with a quartzite.

28. In the twenty-eighth part we shall consider the case of a medium with a hornfels.

29. The twenty-ninth part is devoted to the case of a medium with a amphibolite.

30. In the thirtieth part we shall consider the case of a medium with a pyroxenite.

31. The thirty-first part is devoted to the case of a medium with a peridotite.

32. In the thirty-second part we shall consider the case of a medium with a eclogite.

33. The thirty-third part is devoted to the case of a medium with a granulite.

34. In the thirty-fourth part we shall consider the case of a medium with a migmatite.

35. The thirty-fifth part is devoted to the case of a medium with a gneiss.

36. In the thirty-sixth part we shall consider the case of a medium with a schist.

37. The thirty-seventh part is devoted to the case of a medium with a mica-schist.

38. In the thirty-eighth part we shall consider the case of a medium with a quartzite.

39. The thirty-ninth part is devoted to the case of a medium with a hornfels.

40. In the fortieth part we shall consider the case of a medium with a amphibolite.

41. The forty-first part is devoted to the case of a medium with a pyroxenite.

42. In the forty-second part we shall consider the case of a medium with a peridotite.

43. The forty-third part is devoted to the case of a medium with a eclogite.

44. In the forty-fourth part we shall consider the case of a medium with a granulite.

45. The forty-fifth part is devoted to the case of a medium with a migmatite.

46. In the forty-sixth part we shall consider the case of a medium with a gneiss.

47. The forty-seventh part is devoted to the case of a medium with a schist.

48. In the forty-eighth part we shall consider the case of a medium with a mica-schist.

49. The forty-ninth part is devoted to the case of a medium with a quartzite.

50. In the fiftieth part we shall consider the case of a medium with a hornfels.

51. The fifty-first part is devoted to the case of a medium with a amphibolite.

52. In the fifty-second part we shall consider the case of a medium with a pyroxenite.

53. The fifty-third part is devoted to the case of a medium with a peridotite.

54. In the fifty-fourth part we shall consider the case of a medium with a eclogite.

55. The fifty-fifth part is devoted to the case of a medium with a granulite.

56. In the fifty-sixth part we shall consider the case of a medium with a migmatite.

57. The fifty-seventh part is devoted to the case of a medium with a gneiss.

58. In the fifty-eighth part we shall consider the case of a medium with a schist.

59. The fifty-ninth part is devoted to the case of a medium with a mica-schist.

60. In the sixtieth part we shall consider the case of a medium with a quartzite.

61. The sixty-first part is devoted to the case of a medium with a hornfels.

62. In the sixty-second part we shall consider the case of a medium with a amphibolite.

63. The sixty-third part is devoted to the case of a medium with a pyroxenite.

64. In the sixty-fourth part we shall consider the case of a medium with a peridotite.

65. The sixty-fifth part is devoted to the case of a medium with a eclogite.

66. In the sixty-sixth part we shall consider the case of a medium with a granulite.

67. The sixty-seventh part is devoted to the case of a medium with a migmatite.

68. In the sixty-eighth part we shall consider the case of a medium with a gneiss.

69. The sixty-ninth part is devoted to the case of a medium with a schist.

70. In the seventieth part we shall consider the case of a medium with a mica-schist.

71. The seventy-first part is devoted to the case of a medium with a quartzite.

72. In the seventy-second part we shall consider the case of a medium with a hornfels.

73. The seventy-third part is devoted to the case of a medium with a amphibolite.

74. In the seventy-fourth part we shall consider the case of a medium with a pyroxenite.

75. The seventy-fifth part is devoted to the case of a medium with a peridotite.

76. In the seventy-sixth part we shall consider the case of a medium with a eclogite.

77. The seventy-seventh part is devoted to the case of a medium with a granulite.

78. In the seventy-eighth part we shall consider the case of a medium with a migmatite.

79. The seventy-ninth part is devoted to the case of a medium with a gneiss.

80. In the eightieth part we shall consider the case of a medium with a schist.

81. The eighty-first part is devoted to the case of a medium with a mica-schist.

82. In the eighty-second part we shall consider the case of a medium with a quartzite.

83. The eighty-third part is devoted to the case of a medium with a hornfels.

84. In the eighty-fourth part we shall consider the case of a medium with a amphibolite.

85. The eighty-fifth part is devoted to the case of a medium with a pyroxenite.

86. In the eighty-sixth part we shall consider the case of a medium with a peridotite.

87. The eighty-seventh part is devoted to the case of a medium with a eclogite.

88. In the eighty-eighth part we shall consider the case of a medium with a granulite.

89. The eighty-ninth part is devoted to the case of a medium with a migmatite.

90. In the ninetieth part we shall consider the case of a medium with a gneiss.

91. The ninety-first part is devoted to the case of a medium with a schist.

92. In the ninety-second part we shall consider the case of a medium with a mica-schist.

93. The ninety-third part is devoted to the case of a medium with a quartzite.

94. In the ninety-fourth part we shall consider the case of a medium with a hornfels.

95. The ninety-fifth part is devoted to the case of a medium with a amphibolite.

96. In the ninety-sixth part we shall consider the case of a medium with a pyroxenite.

97. The ninety-seventh part is devoted to the case of a medium with a peridotite.

98. In the ninety-eighth part we shall consider the case of a medium with a eclogite.

99. The ninety-ninth part is devoted to the case of a medium with a granulite.

100. In the hundredth part we shall consider the case of a medium with a migmatite.

(5) Frequencies observed by months.

These histograms are shown in Figures 1 and 2.

From these histograms a few qualitative forecast aids can be formulated:

(1) There is a tendency for sea level and 500 mb half-waves to have the same semi-periods. However, the maximum number of 500 mb semi-periods was observed to occur at 1.0 days, while the maximum for sea level half-waves occurred at 1.5 days. The average semi-period for waves at the two levels was almost the same, as would be expected. Evidently several short waves at 500 mb are followed by an unusually long one to get the wave trains at the two levels back in phase. Table 14 shows the number of observations of each semi-period.

(2) The average lag between 500 mb and sea level waves is approximately +12 hours (sea level wave leads the 500 mb wave).

(3) As a general rule, the range increases with increasing sea level semi-period. This is true at both sea level and 500 mb, but more so at 500 mb. The correlation between sea level and 500 mb range for the 31 sea level semi-periods of 1.5 days was found to be only 0.23.

(4) The division of sea level semi-periods by months for the winter season studied appears to be random.

Summarizing, this investigation determined that, although certain periodicities can be detected, it is difficult, if not impossible, to forecast them. Furthermore, it is just as difficult to forecast how long

Entered as Second-Class Matter, May 2, 1882. Postpaid at Special Rate of \$3.75 per Annum. Approved for mailing at Special Rate of \$3.75 per Annum. Postpaid at Special Rate of \$3.75 per Annum.

Copyright, 1919, by American Medical Association

Published by the American Medical Association, 535 North Dearborn Street, Chicago, Ill.

Subscription price, Five Dollars per Annum in Advance

Single Copies, Fifteen Cents

Entered as Second-Class Matter, May 2, 1882. Postpaid at Special Rate of \$3.75 per Annum.

Approved for mailing at Special Rate of \$3.75 per Annum.

Postpaid at Special Rate of \$3.75 per Annum.

Postpaid at Special Rate of \$3.75 per Annum.

Postpaid at Special Rate of \$3.75 per Annum.

Postpaid at Special Rate of \$3.75 per Annum.

Postpaid at Special Rate of \$3.75 per Annum.

Postpaid at Special Rate of \$3.75 per Annum.

Postpaid at Special Rate of \$3.75 per Annum.

Postpaid at Special Rate of \$3.75 per Annum.

Postpaid at Special Rate of \$3.75 per Annum.

Postpaid at Special Rate of \$3.75 per Annum.

Postpaid at Special Rate of \$3.75 per Annum.

Postpaid at Special Rate of \$3.75 per Annum.

Postpaid at Special Rate of \$3.75 per Annum.

Postpaid at Special Rate of \$3.75 per Annum.

Postpaid at Special Rate of \$3.75 per Annum.

Postpaid at Special Rate of \$3.75 per Annum.

Postpaid at Special Rate of \$3.75 per Annum.

Postpaid at Special Rate of \$3.75 per Annum.

Postpaid at Special Rate of \$3.75 per Annum.

Postpaid at Special Rate of \$3.75 per Annum.

one particular period will persist. It was found that the average period for both sea level and 500 mb waves at Columbia during the winter studied was 3.4 days. This period is in good agreement with the 3-day period used in 'weather type' forecasting but cannot be used for accurate day to day 500 mb prognostication.

TABLE 8

Means

$$\bar{X}_2 = -1.0536$$

$$\bar{X}_6 = -0.8571$$

$$\bar{X}_7 = 0.8036$$

Standard Deviations

$$\sigma_{x_2} = 4.4658$$

$$\sigma_{x_6} = 4.9513$$

$$\sigma_{x_7} = 4.8528$$

Simple Correlation Statistics

$$r_{26} = 0.7886$$

$$X_2 = 0.7113 X_6 - 0.4440$$

$$r_{27} = -0.7890$$

$$X_7 = -0.8574 X_2 - 0.0997$$

$$r_{67} = -0.8275$$

$$X_7 = -0.8110 X_6 + 0.1075$$

Multiple Correlation Statistics

$$r_{7,26} = 0.8556$$

$$S_{7,26} = 2.5031$$

$$X_7 = -0.391 X_2 - 0.533 X_6 - 0.065$$

Statistics of 36 - Hour Tendencies for Winter
Troughs and Ridges (Number in Sample = 56)

12

$$f(x) = \frac{1}{x^2} \quad f'(x) = -\frac{2}{x^3} \quad f''(x) = \frac{6}{x^4}$$

continued fraction

$$f(x) = \frac{1}{1-x} \quad f'(x) = \frac{1}{(1-x)^2} \quad f''(x) = \frac{2}{(1-x)^3}$$

continued fraction expansion

$$\begin{aligned} f(x) &= \frac{1}{1-x} = \frac{1}{1-x} \\ f'(x) &= \frac{1}{(1-x)^2} = \frac{1}{1-x} + \frac{x}{(1-x)^2} \\ f''(x) &= \frac{2}{(1-x)^3} = \frac{2}{1-x} + \frac{4x}{(1-x)^2} + \frac{2x^2}{(1-x)^3} \end{aligned}$$

continued fraction expansion

$$\begin{aligned} f(x) &= \frac{1}{1-x} \\ f'(x) &= \frac{1}{(1-x)^2} \\ f''(x) &= \frac{2}{(1-x)^3} \end{aligned}$$

continued fraction expansion

TABLE 9

Means

$$\bar{X}_1 = -0.3929 \quad \bar{X}_2 = -1.0536 \quad \bar{X}_3 = 1.1964$$

Standard Deviations

$$\sigma_{x_1} = 4.9449 \quad \sigma_{x_2} = 4.3932 \quad \sigma_{x_3} = 4.8529$$

Simple Correlation Statistics

$$\begin{aligned} r_{13} &= -0.5675 & X_3 &= -0.5569X_1 \quad 0.9776 \\ r_{12} &= 0.7610 & X_2 &= 0.6761X_1 \quad -0.7880 \\ r_{23} &= -0.7410 & X_3 &= -0.8185X_2 \quad 0.3340 \end{aligned}$$

Multiple Correlation Statistics

$$\begin{aligned} r_{3,12} &= 0.7419 & S_{3,12} &= 3.3936 \\ X_3 &= -0.058X_1 - 0.725X_2 \quad 0.408 \end{aligned}$$

Statistics of 3 - Day Tendencies for Winter
Troughs and Ridges (Number in Sample = 56)

Table 1

1970

100.0 = 100.0 100.0 = 100.0 100.0 = 100.0

100.0 = 100.0

100.0 = 100.0 100.0 = 100.0 100.0 = 100.0

100.0 = 100.0

100.0 = 100.0 100.0 = 100.0

100.0 = 100.0 100.0 = 100.0

100.0 = 100.0 100.0 = 100.0

100.0 = 100.0

100.0 = 100.0 100.0 = 100.0

100.0 = 100.0

100.0 = 100.0 100.0 = 100.0

TABLE 10

Means

$$\bar{x}_6 = -0.4140$$

$$\bar{x}_7 = 0.2167$$

Standard Deviations

$$\sigma_{x_6} = 3.7024$$

$$\sigma_{x_7} = 3.6542$$

Simple Correlation Coefficient

$$r_{67} = -0.3319$$

Statistics of 36-Hour Tendencies for all 0300Z Data
in Winter (Number in Sample = 157)

TABLE 11

Means

$$\bar{X}_3 = -0.1300$$

$$\bar{X}_4 = 0.0030$$

Standard Deviations

$$\sigma_{x_3} = 4.1093$$

$$\sigma_{x_4} = 5.6098$$

Simple Correlation Coefficient

$$r_{34} = -0.2345$$

Statistics of Past 3-Day Temperature Change
and Following 3-Day Height Tendency for Winter
(Number in Sample = 300)

1. Introduction

$$\text{mod } 2 = \mathbb{F}_2$$

$$\text{mod } 2 = \mathbb{F}_2$$

$$\text{mod } 2 = \mathbb{F}_2$$

$$\text{mod } 2 = \mathbb{F}_2$$

Consider the following example:

$$(x^2 + 1)^2 = x^4 + 2x^2 + 1$$

Let $f(x) = x^2 + 1$ and $g(x) = x^2 + 1$. Then $f(x)g(x) = x^4 + 2x^2 + 1$. Since $2 \equiv 0 \pmod{2}$, we have $f(x)g(x) = x^4 + 1$ in $\mathbb{F}_2[x]$.

TABLE 12

Means

$$\bar{X}_1 = -0.1167 \quad \bar{X}_2 = 0.0700 \quad \bar{X}_3 = -0.1300 \quad \bar{X}_5 = 1.5700$$

Standard Deviations

$$\sigma_{x_1} = 3.9870 \quad \sigma_{x_2} = 3.4184 \quad \sigma_{x_3} = 4.1093 \quad \sigma_{x_5} = 4.4735$$

Simple Correlation Statistics

$$r_{13} = -0.3385$$

$$r_{32} = -0.5738$$

$$r_{12} = 0.6172$$

$$r_{25} = 0.7594$$

$$r_{35} = -0.4215$$

$$X_3 = -0.6898X_2 - 0.0818$$

$$X_2 = 0.5292X_1 - 0.1318$$

$$X_2 = 0.5803X_5 - 0.8411$$

Multiple Correlation Statistics

$$r_{3.12} = 0.5742$$

$$S_{3.12} = 3.3645$$

$$X_3 = 0.026X_1 - 0.696X_2 - 0.078$$

$$r_{3.25} = 0.5742$$

$$S_{3.25} = 3.3645$$

$$X_3 = 0.030X_5 - 0.718X_2 - 0.127$$

Statistics of 3-Day Tendencies for all Winter Data
(Number in Sample = 300)

Table 1

1979

$$1979.1 = 20 \quad 1979.2 = 20 \quad 1979.3 = 20 \quad 1979.4 = 20$$

1980/1981

$$1980.1 = 20 \quad 1980.2 = 20 \quad 1980.3 = 20 \quad 1980.4 = 20$$

1981/1982

$$\begin{aligned} 1981.1 &= 20 & 1981.2 &= 20 \\ 1981.3 &= 20 & 1981.4 &= 20 \\ 1981.5 &= 20 & 1981.6 &= 20 \\ 1981.7 &= 20 & 1981.8 &= 20 \end{aligned}$$

1982/1983

$$\begin{aligned} 1982.1 &= 20 & 1982.2 &= 20 \\ 1982.3 &= 20 & 1982.4 &= 20 \\ 1982.5 &= 20 & 1982.6 &= 20 \\ 1982.7 &= 20 & 1982.8 &= 20 \end{aligned}$$

1983/1984

TABLE 13

Means

$$\bar{X}_1 = 0.0259 \quad \bar{X}_2 = -0.2529 \quad \bar{X}_3 = 0.1063 \quad \bar{X}_5 = 0.6351$$

Standard Deviations

$$\sigma_{x_1} = 2.3186 \quad \sigma_{x_2} = 1.9429 \quad \sigma_{x_3} = 2.3250 \quad \sigma_{x_5} = 2.6623$$

Simple Correlation Statistics

$$r_{13} = -0.3118$$

$$r_{32} = -0.5475$$

$$r_{12} = 0.6196$$

$$r_{25} = 0.6732$$

$$r_{35} = -0.3739$$

$$X_3 = -0.6552X_2 - 0.0594$$

$$X_2 = 0.5192X_1 - 0.2663$$

$$X_2 = 0.4913X_5 - 0.5649$$

Multiple Correlation Statistics

$$r_{3.12} = 0.5485$$

$$S_{3.12} = 1.9439$$

$$X_3 = 0.045X_1 - 0.680X_2 - 0.069$$

Statistics of 3-Day Tendencies for all Summer Data
(Number in Sample = 348)

Table

Page

1. $\log 2 = 0.30103$ 2. $\log 3 = 0.47712$ 3. $\log 4 = 0.60206$ 4. $\log 5 = 0.69897$

5. $\log 6 = 0.77815$ 6. $\log 7 = 0.84509$ 7. $\log 8 = 0.90309$ 8. $\log 9 = 0.95424$

9. $\log 10 = 1.00000$ 10. $\log 11 = 1.04139$ 11. $\log 12 = 1.07918$ 12. $\log 13 = 1.11394$

13. $\log 14 = 1.14613$ 14. $\log 15 = 1.17609$ 15. $\log 16 = 1.20412$ 16. $\log 17 = 1.23045$

17. $\log 18 = 1.25527$ 18. $\log 19 = 1.27875$ 19. $\log 20 = 1.30103$

20. $\log 21 = 1.32222$ 21. $\log 22 = 1.34242$ 22. $\log 23 = 1.36173$

23. $\log 24 = 1.38021$ 24. $\log 25 = 1.39794$ 25. $\log 26 = 1.41492$

26. $\log 27 = 1.43136$ 27. $\log 28 = 1.44715$ 28. $\log 29 = 1.46239$

29. $\log 30 = 1.47712$ 30. $\log 31 = 1.49136$ 31. $\log 32 = 1.50515$

32. $\log 33 = 1.51876$ 33. $\log 34 = 1.53209$ 34. $\log 35 = 1.54507$

35. $\log 36 = 1.55874$ 36. $\log 37 = 1.57209$ 37. $\log 38 = 1.58504$

38. $\log 39 = 1.59763$ 39. $\log 40 = 1.60206$ 40. $\log 41 = 1.61278$

41. $\log 42 = 1.62325$ 42. $\log 43 = 1.63447$ 43. $\log 44 = 1.64622$

44. $\log 45 = 1.65321$ 45. $\log 46 = 1.66037$ 46. $\log 47 = 1.66763$

47. $\log 48 = 1.67504$ 48. $\log 49 = 1.68256$ 49. $\log 50 = 1.68907$

50. $\log 51 = 1.69565$ 51. $\log 52 = 1.70233$ 52. $\log 53 = 1.70913$

53. $\log 54 = 1.71594$ 54. $\log 55 = 1.72277$ 55. $\log 56 = 1.72972$
56. $\log 57 = 1.73679$ 57. $\log 58 = 1.74387$ 58. $\log 59 = 1.75097$

TABLE 14

Semi-Period (Days)	Sea Level Frequency	500 mb Frequency
0.5	9	11
1.0	15	27
1.5	31	18
2.0	17	12
2.5	10	11
3.0	2	4
3.5	3	1
4.0	1	2
4.5	0	1
5.0	1	1
5.5	0	0
6.0	0	1
6.5	<u>1</u>	<u>1</u>
Total	90	90
Average	1.71	1.73

Number of Observed Semi-Periods at Sea Level and 500 mb

TABLE 2

Summary of the results of the analysis of variance for the different groups of subjects

Group	Sum of Squares	D.F.	Mean Square	F	Significance
1	1.2	1	1.2	1.2	0.3
2	1.2	1	1.2	1.2	0.3
3	1.2	1	1.2	1.2	0.3
4	1.2	1	1.2	1.2	0.3
5	1.2	1	1.2	1.2	0.3
6	1.2	1	1.2	1.2	0.3
7	1.2	1	1.2	1.2	0.3
8	1.2	1	1.2	1.2	0.3
9	1.2	1	1.2	1.2	0.3
10	1.2	1	1.2	1.2	0.3
11	1.2	1	1.2	1.2	0.3
12	1.2	1	1.2	1.2	0.3
13	1.2	1	1.2	1.2	0.3
14	1.2	1	1.2	1.2	0.3
15	1.2	1	1.2	1.2	0.3
16	1.2	1	1.2	1.2	0.3
17	1.2	1	1.2	1.2	0.3
18	1.2	1	1.2	1.2	0.3
19	1.2	1	1.2	1.2	0.3
20	1.2	1	1.2	1.2	0.3
21	1.2	1	1.2	1.2	0.3
22	1.2	1	1.2	1.2	0.3
23	1.2	1	1.2	1.2	0.3
24	1.2	1	1.2	1.2	0.3
25	1.2	1	1.2	1.2	0.3
26	1.2	1	1.2	1.2	0.3
27	1.2	1	1.2	1.2	0.3
28	1.2	1	1.2	1.2	0.3
29	1.2	1	1.2	1.2	0.3
30	1.2	1	1.2	1.2	0.3
31	1.2	1	1.2	1.2	0.3
32	1.2	1	1.2	1.2	0.3
33	1.2	1	1.2	1.2	0.3
34	1.2	1	1.2	1.2	0.3
35	1.2	1	1.2	1.2	0.3
36	1.2	1	1.2	1.2	0.3
37	1.2	1	1.2	1.2	0.3
38	1.2	1	1.2	1.2	0.3
39	1.2	1	1.2	1.2	0.3
40	1.2	1	1.2	1.2	0.3
41	1.2	1	1.2	1.2	0.3
42	1.2	1	1.2	1.2	0.3
43	1.2	1	1.2	1.2	0.3
44	1.2	1	1.2	1.2	0.3
45	1.2	1	1.2	1.2	0.3
46	1.2	1	1.2	1.2	0.3
47	1.2	1	1.2	1.2	0.3
48	1.2	1	1.2	1.2	0.3
49	1.2	1	1.2	1.2	0.3
50	1.2	1	1.2	1.2	0.3
51	1.2	1	1.2	1.2	0.3
52	1.2	1	1.2	1.2	0.3
53	1.2	1	1.2	1.2	0.3
54	1.2	1	1.2	1.2	0.3
55	1.2	1	1.2	1.2	0.3
56	1.2	1	1.2	1.2	0.3
57	1.2	1	1.2	1.2	0.3
58	1.2	1	1.2	1.2	0.3
59	1.2	1	1.2	1.2	0.3
60	1.2	1	1.2	1.2	0.3
61	1.2	1	1.2	1.2	0.3
62	1.2	1	1.2	1.2	0.3
63	1.2	1	1.2	1.2	0.3
64	1.2	1	1.2	1.2	0.3
65	1.2	1	1.2	1.2	0.3
66	1.2	1	1.2	1.2	0.3
67	1.2	1	1.2	1.2	0.3
68	1.2	1	1.2	1.2	0.3
69	1.2	1	1.2	1.2	0.3
70	1.2	1	1.2	1.2	0.3
71	1.2	1	1.2	1.2	0.3
72	1.2	1	1.2	1.2	0.3
73	1.2	1	1.2	1.2	0.3
74	1.2	1	1.2	1.2	0.3
75	1.2	1	1.2	1.2	0.3
76	1.2	1	1.2	1.2	0.3
77	1.2	1	1.2	1.2	0.3
78	1.2	1	1.2	1.2	0.3
79	1.2	1	1.2	1.2	0.3
80	1.2	1	1.2	1.2	0.3
81	1.2	1	1.2	1.2	0.3
82	1.2	1	1.2	1.2	0.3
83	1.2	1	1.2	1.2	0.3
84	1.2	1	1.2	1.2	0.3
85	1.2	1	1.2	1.2	0.3
86	1.2	1	1.2	1.2	0.3
87	1.2	1	1.2	1.2	0.3
88	1.2	1	1.2	1.2	0.3
89	1.2	1	1.2	1.2	0.3
90	1.2	1	1.2	1.2	0.3
91	1.2	1	1.2	1.2	0.3
92	1.2	1	1.2	1.2	0.3
93	1.2	1	1.2	1.2	0.3
94	1.2	1	1.2	1.2	0.3
95	1.2	1	1.2	1.2	0.3
96	1.2	1	1.2	1.2	0.3
97	1.2	1	1.2	1.2	0.3
98	1.2	1	1.2	1.2	0.3
99	1.2	1	1.2	1.2	0.3
100	1.2	1	1.2	1.2	0.3

NOTE: The results of the analysis of variance for the different groups of subjects are given in Table 2.

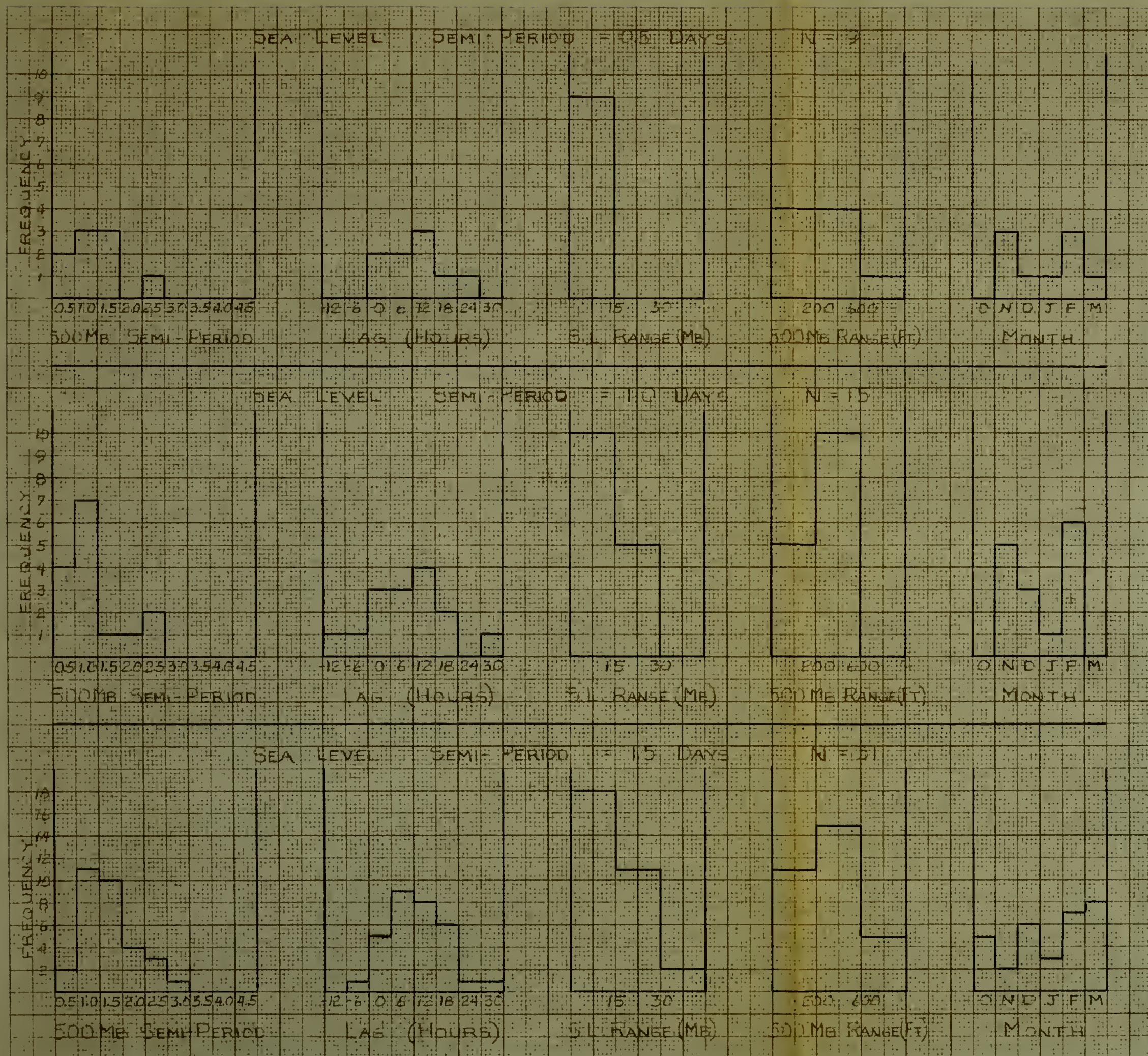
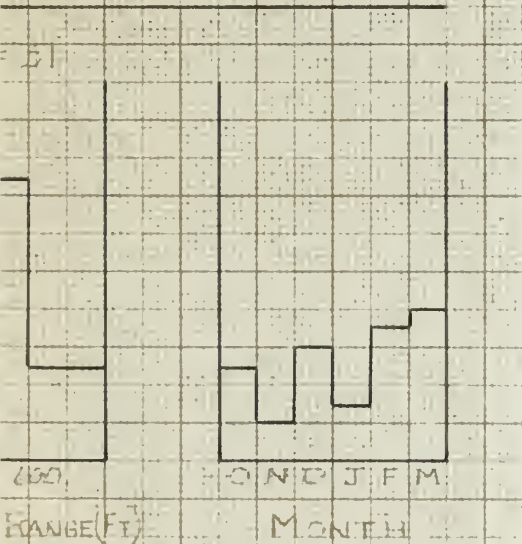
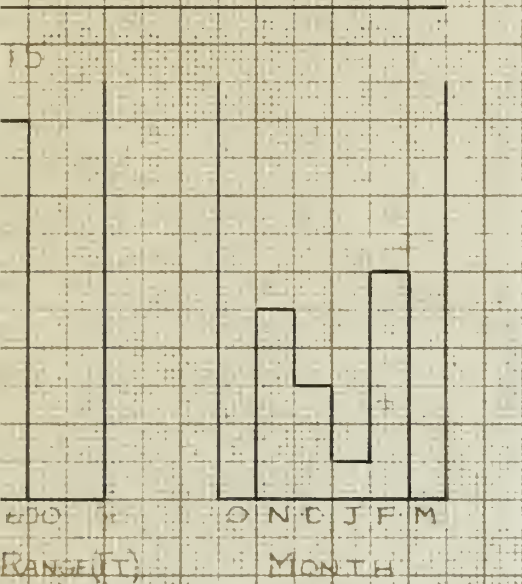


Figure 1.



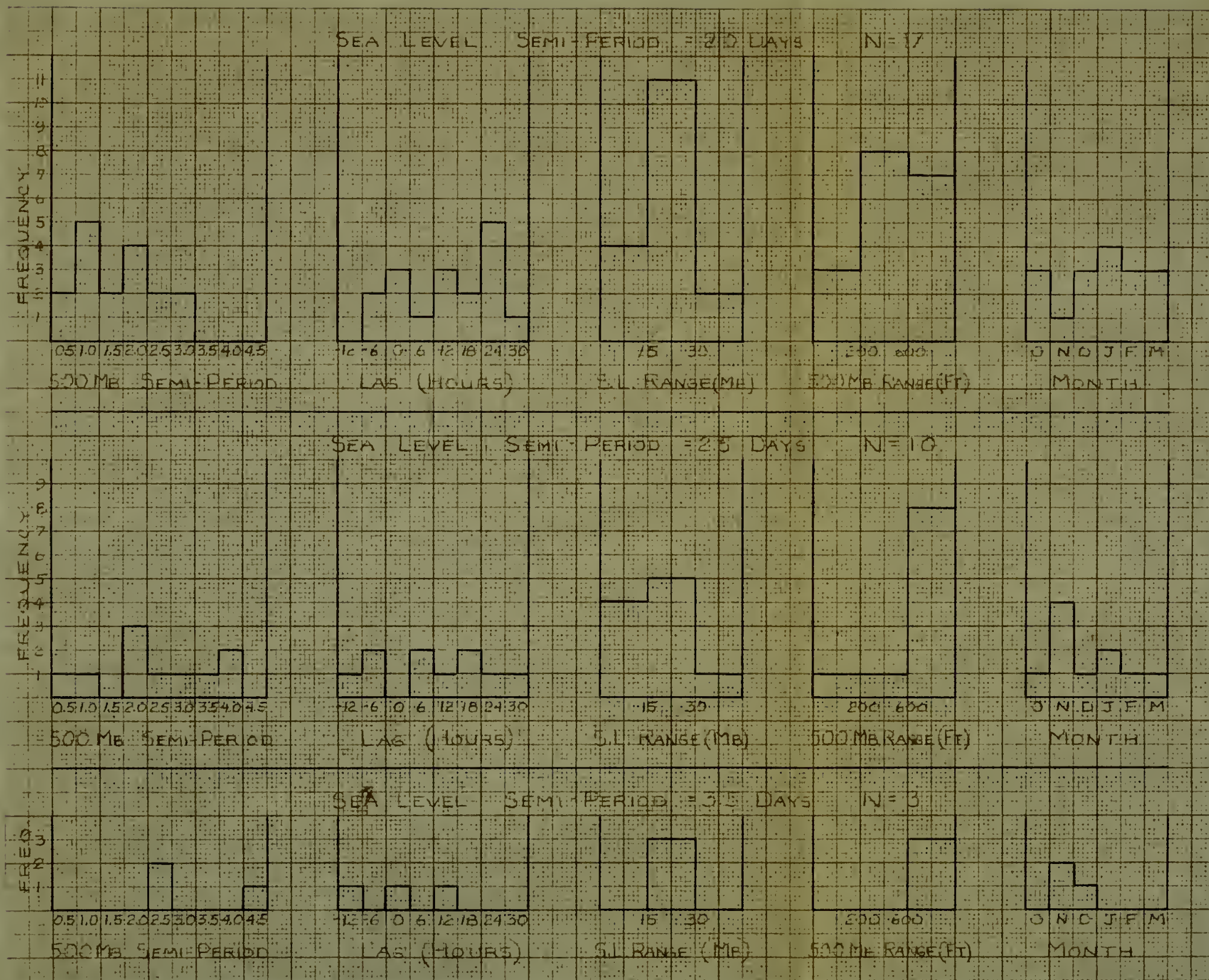
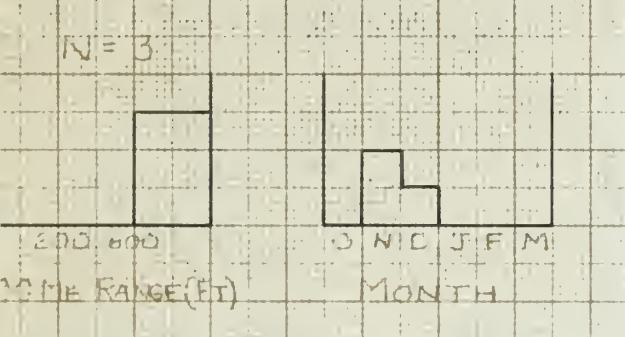
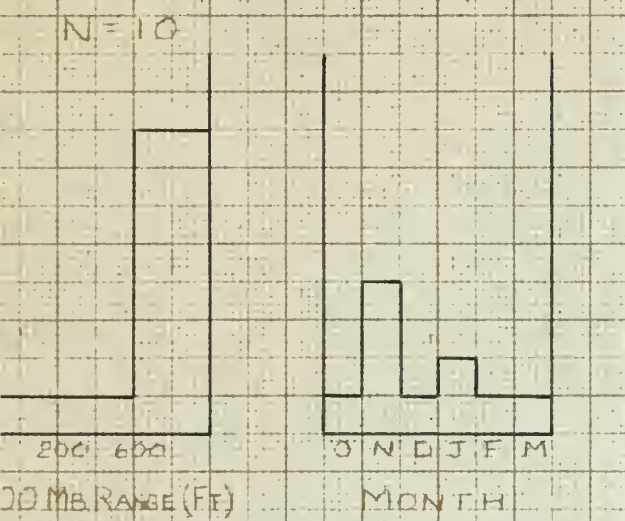
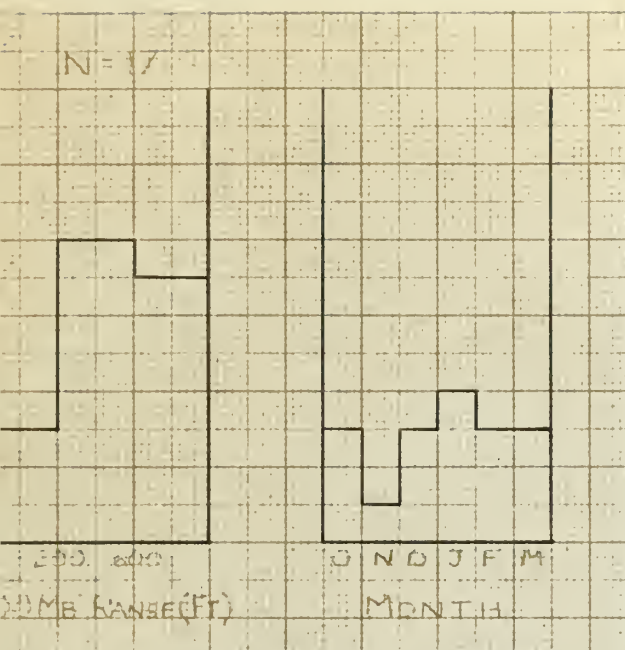


Figure 2.



BIBLIOGRAPHY

1. Aime, E. A. and E. C. Johnson. Methods for the Preparation of Six-day Forecasts. Washington, D. C., U. S. Weather Bureau, November 1943.
2. Bellamy, J. C. The Use of Pressure Altitude and Altimeter Corrections in Meteorology. Journal Meteor. 1, 22, 1945.
3. Maurwitz, B. Final Report on the Use of Symmetry Points in the Pressure Curves for Long-range Forecasting. Weather Division, Headquarters Army Air Forces. March 1944 (Massachusetts Institute of Technology. Report No. 709).
4. Joint Meteorological Committee, Normal Weather Maps, Northern Hemisphere Upper Level. Washington, D. C., U. S. Weather Bureau, October, 1944.
5. Krick, I. P. A Dynamical Theory of the Atmospheric Circulation and its Use in Weather Forecasting, Meteor. Report, California Institute of Technology, February, 1942.
6. U. S. Weather Bureau, Daily Upper Air Bulletin. Washington, D. C., October 1948-September 1949.

CHAPTER I

1. The first part of the book is devoted to a general survey of the subject.

2. The second part is devoted to a detailed study of the various aspects of the subject.

3. The third part is devoted to a study of the various methods of research.

4. The fourth part is devoted to a study of the various results of research.

5. The fifth part is devoted to a study of the various applications of the subject.

6. The sixth part is devoted to a study of the various conclusions of the subject.

APR 22 1964 T.L. (JBG) 765
3rd T.L.
DEC 23 4.T.L. RENEWED

Thesis 13126
H84

Hubert, Wm. E.

AUTHOR

A study of heighttendencies at

TITLE

the 500 MB level.

thesH84

A study of height tendencies at the 500



3 2768 002 13196 3

DUDLEY KNOX LIBRARY